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REVIEW OF JAMES RIVER INVESTIGATION, WITH REFERENCE TO PROPOSED GATHRIGHT RESERVOIR AND FALLING SPRING REREGULATING DAM

Donald D. Gold, et al

Environmental Health Center
Cincinnati, Ohio

August 1953

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AND
FALLING SPRING REREGULATING DAM

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U.S. DEPARTMENT OF
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ENVIRONMENTAL HEALTH CENTER
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REVIEW OF JAMES RIVER INVESTIGATION

With Reference to Proposed Gathright Reservoir and Falling Spring Reregulating Dam

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By

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and

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Prepared by the U. S. Public Health Service
at the request of the District Engineer,
Corps of Engineers, Norfolk, Virginia

Introduction

This report has been prepared at the request of the District Engineer, Corps of Engineers, Norfolk, Virginia, transmitted verbally at a meeting on December 3, 1952, and subsequently confirmed by letter dated December 13, 1952. A revision of a previous report by Richard L. Woodward, Sanitary Engineer, and M. LaBosquet, Jr., Sanitary Engineer, dated 1949, is needed in order to bring it up to date so it may be used by the District Engineer in the preparation of a definite project report on the Gathright-Falling Spring Reservoir on the Jackson River, a headwater tributary of the James River, Virginia.

The data relating to progress in pollution abatement since 1949 have been obtained from records of the Virginia Water Control Board and the Virginia Department of Health. This assistance is gratefully acknowledged. The conclusions given and the opinions expressed are those of the U. S. Public Health Service.

Summary and Conclusions

(1) Low-flow regulation is a very important part of a comprehensive program of pollution abatement on the Jackson and upper James Rivers. Together with a general program of waste treatment and other measures aimed at reducing the pollution load, flow regulation can increase the usefulness of the James River for public water supplies, for agricultural and industrial use, for recreation and for wildlife conservation.

(2) The benefits, both tangible and intangible, to be derived from a comprehensive pollution abatement program on the upper James River are widespread. All who use the water of the James River will benefit.

(3) The problem of estimating these benefits in monetary terms and of allocating the cost to each water user is one which cannot be solved in any exact manner. The monetary value of the benefits of low-flow regulation has been estimated on the basis of the cost of achieving reasonably similar results by other means. The estimates are believed to be conservative.

(4) Although flow regulation is an important part of a comprehensive pollution abatement program for the Jackson and upper James Rivers, it will be necessary for local interests discharging to the two rivers to spend some $21,000,000 on intercepting sewers, treatment plants, industrial process changes and recovery systems. This does not include $2,300,000 to be spent by municipalities discharging to tributaries of the James River. Expenditures of $6,310,000 which have already been made by industry and communities are not included. This is a real and essential contribution to the pollution abatement program.

(5) The Virginia Water Control Law adopted in 1946 provides strong antipollution legislation for Virginia. This legislation, the submission of plans and reports to the Virginia Water Control Board and to the Virginia Department of Health, and the progress being made, indicate that the necessary industrial waste corrective measures and the necessary municipal sewage treatment plants may be provided within a reasonable time.

(6) When impoundment of water in the Gathright-Falling Spring Reservoir is commenced, it is recommended that the naturally occurring flow of the Jackson River up to 120 cfs to be released during the months of May through October, and up to 70 cfs be released during the months of November through April providing that Covington and Clifton Forge have installed primary sewage treatment and the West Virginia Pulp and Paper Company have completed the installation of activated sludge treatment or its equivalent for their wastes.

Sources of Pollution - February, 1953

A survey made in February, 1953, revealed that the James River and its tributaries received sewage from a population of 414,000, and industrial wastes equivalent* to sewage from an additional 1,426,000 people. The major areas of heavy pollution are: (a) the Jackson River in the vicinity of Covington and Clifton Forge, (b) the James River in the vicinity of Big Island and Lynchburg, and (c) the James River at and below Richmond. Table 1 shows data on sources of pollution in the basin, and figure 1 shows similar information graphically.

Developments in Pollution Abatement

The Commonwealth of Virginia adopted a Water Control Law on March 30, 1946, for the purpose of abating water pollution. Under that law, certificates must be obtained from the Water Control Board by each community or industry discharging pollution to any waters of Virginia. Reports are called for periodically to indicate what progress has been

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* In terms of Biochemical Oxygen Demand, a measure of the oxygen-depleting strength of the wastes.

Table 1 - James River Investigation - Sources of Pollution Including Industrial Waste Discharging to Streams in James River Basin

Municipal-Industrial Source of Pollution	River M'les Above Mouth	Est. Population served	Treatment	Sewered Population Equivalent (B.O.D.)	
				Untreated	Discharged
Jackson River	339.7				
West Virginia Pulp&Paper Co.	24.5	---	None	124,800	124,800
Covington	23.9	11,140	None	11,140	11,140
Alleghany County		600	None	600	600
Industrial Rayon Corp.	19.5	---	None	10,000	10,000
Selma	6.0	220	None	220	220
Clifton Forge	3.7	6,000	None	6,000	6,000
Iron Gate	1.2	650	None	650	650
James River					
National Container Corp. Big Island	270.4	---	Lagoon	233,500	233,500
E.J. Levino Co., Lynchburg		---	None		
Lynchburg	251.7	47,700	None	68,000	68,000
Meade Corp., Lynchburg	250.0	---	None	250,000	250,000
Madison Heights San. Dist.	250.0	1,000	None	1,000	1,000
Lynchburg State Colony	249.0	1,500	Primary	1,500	1,000
Lynchburg Rendering Co.		---	None	9,500	9,500
Scottsville	184.7	400	None	400	400
Fork Union Military Academy		300	None	300	300
St. Emma's Institute		200	Primary	200	150
Beaumont Industrial School	136.0	360	Primary	360	240
State Industrial Farm for Women, Goochland	136.0	600	Secondary	600	90

Table 1 - (continued)

Municipal-Industrial Source at Pollution	River Miles Above Mouth*	Est.Population served	Treatment	Sewered Population Equivalent (BOD) Untreated	Sewered Population Equivalent (BOD) Discharged
Misdemeanant Farm, Powhatan		500	Secondary	500	50
Virginia State Farm	135.0	600	Secondary	600	90
State Farm Laundry	135.0		Primary		
Manchester Board & Paper Co. Richmond		—	None	7,000	7,000
Standard Paper Mfg. Richmond		—	Lagoon		13,000
Albemarle Paper Co. Richmond		—	None		2,300
Richmond	103.6	230,000	None	230,000	230,000
Virginia-Carolina Chem. Corp., Richmond		—	None	12,000	12,000
E. I. du Pont (Spruance Plant) Richmond		—	Neutralization	50,900	50,900
Richmond Quartermaster Depot, U.S. Army		400	None	400	400
National Aniline Div., Allied Chemical & Dye Corp., Hopewell		Plant	Under Construction		
Nitrogen Div., Allied Chemical & Dye Corp., Hopewell			Primary	1,600	500
Hummel Ross Div., Continental Can Co., Hopewell		—	None	179,600	179,600
Hercules Powder Co. Hopewell		—	None	479,000	479,000
Fort Lee			Primary		
Hopewell	69.5	16,000	None	16,000	16,000
Celanese Corp. of Amer. Hopewell		—	None	9,000	9,000

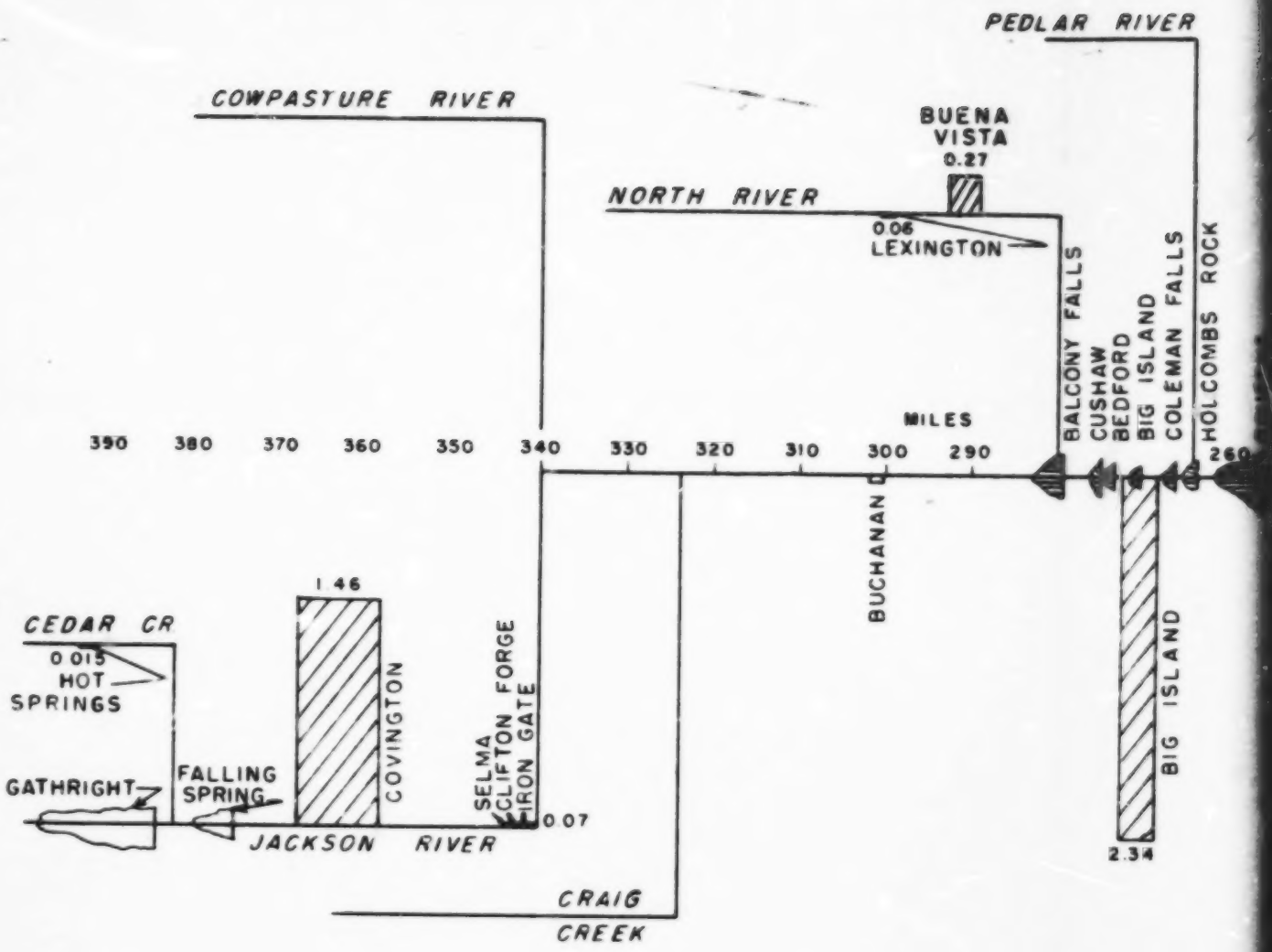
Table 1-(continued)

Municipal-Industrial Source at Pollution	River Miles Above Mouthe	Est. Population served	Treatment	Sewered Population Equivalent (B.C.D.) Untreated	Discharged
Cedar Creek -trib. Jackson R.					
Hot Springs		1,500	Secondary	1,500	250
North River(MavryRiver)	279.9				
Lexington	20.0	6,000	None	6,000	6,000
Piedmont PaperProducts Inc., Buena Vista		---	None		
Lees McVitty Corp., Buena Vista		---	Lagoon		12,000
Buena Vista	11.3	3,000	None	3,000	3,000
James LeesdSonsGlasgow		---	Primary	28,000	12,000
Cedar Creek-trib.James R.					
Natural Bridge		450	Primary	450	300
Piney River-trib.Tye, Buffalo R.,James R.					
American Cyanamid Co.Calco ChemicalDiv.(PineyRiverPlant)					
Rutledge Creek-trib.BuffaloR. James R.					
Sweet Briar College		750	Secondary	750	80
Amherst		800	Primary	800	500
Rivanna River	162.1				
Charlottesville Woolen Mill	36.2	---	None		
Charlottesville	36.1	24,000	2Primary Plants	24,000	20,000
Blue Ridge Sanatorium		500	Secondary	500	50

Table 1 - (continued)

Municipal-Industrial Source at Pollution	River Miles Above Mouth	Est. Population served	Treatment	Sewered Population Equivalent (BOD)	
				Untreated	Discharged
Appomatox River	71.6				
Farmville	109.2	5,200	None	5,200	5,200
Birtchard's Dairy		—	Secondary	1,100	390
Central State Hospital	12.9	4,500	None	4,500	4,500
Ettrick San. Dist.	11.8	1,300	None	1,300	1,300
Petersburg	11.8	35,000	None	35,000	35,000
Petersburg Federal Reformatory	5.5	1,000	Secondary	1,000	150
Little Buffalo Creek trib.	110.0				
Appomatox River					
Hampden-Sydney College	5.0	600	Secondary	600	200
Deep Creek trib. Appomatox R.	40.0				
Crewe	21.5	2,000	None	2,000	2,000
Old Town Creek trib. Appomatox R.	3.0				
Colonial Heights	1.0	8,000	Primary	8,000	5,000
Total		412,770		1,829,070	1,825,350

* River mileage to mouth of James. Others to mouth of tributary.


PEDLAR RIVER
COWPASTURE RIVER
BUENA VISTA
0.27
NORTH RIVER
0.06
LEXINGTON
BALCONY FALLS
CUSHAW
BEDFORD
BIG ISLAND
COLEMAN FALLS
HOLCOMBS ROCK
MILES
390 380 370 360 350 340 330 320 310 300 290 260
BUCHANAN
1.46
CEDAR CR
0.015
HOT SPRINGS
COVINGTON
SELMA
CLIFTON FORGE
IRON GATE
0.07
GATHRIGHT
FALLING SPRING
JACKSON RIVER
BIG ISLAND
2.34
CRAIG CREEK

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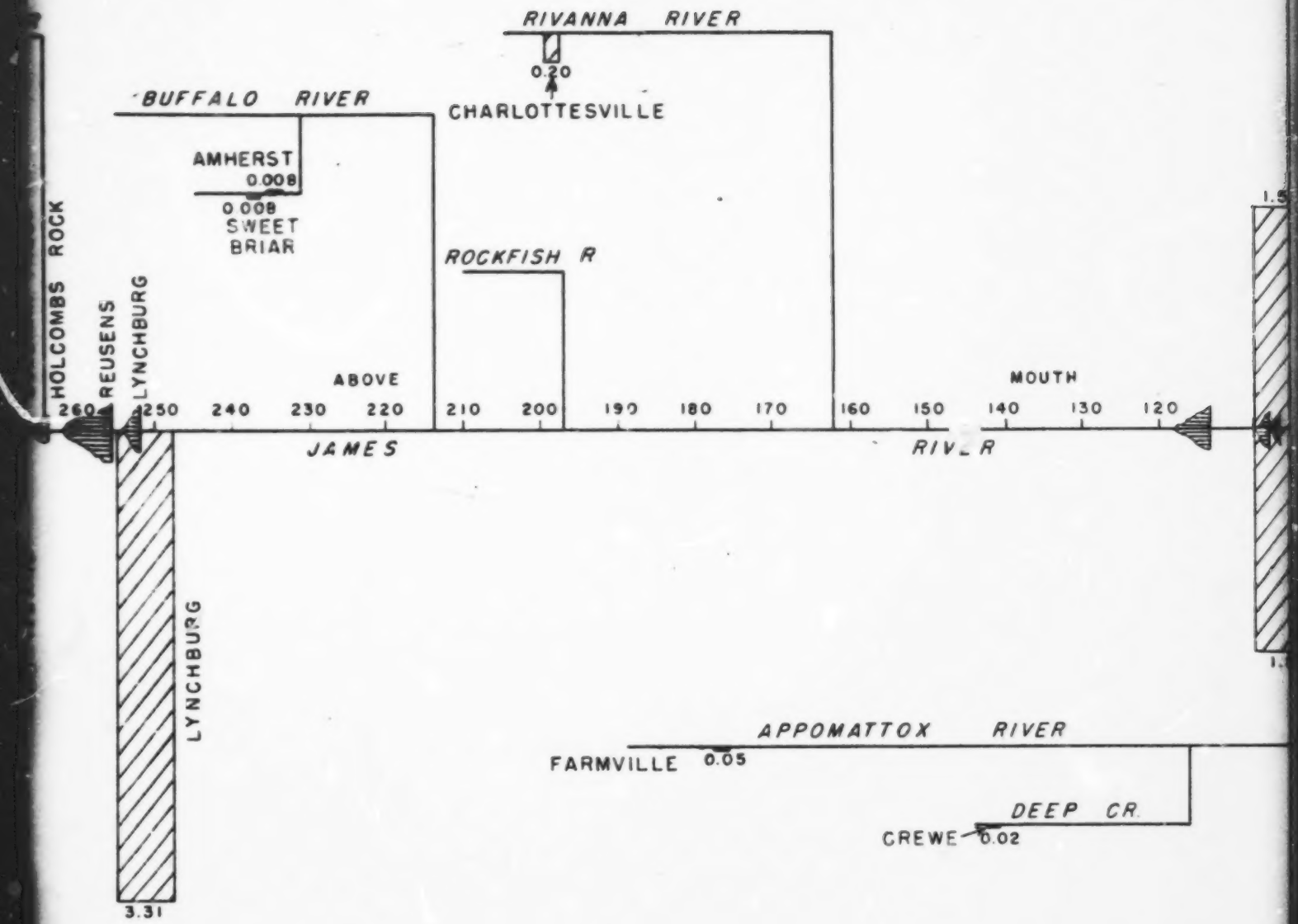

SOURCES OF POLLUTION

JAMES RIVER

APRIL, 1953

B

4.D

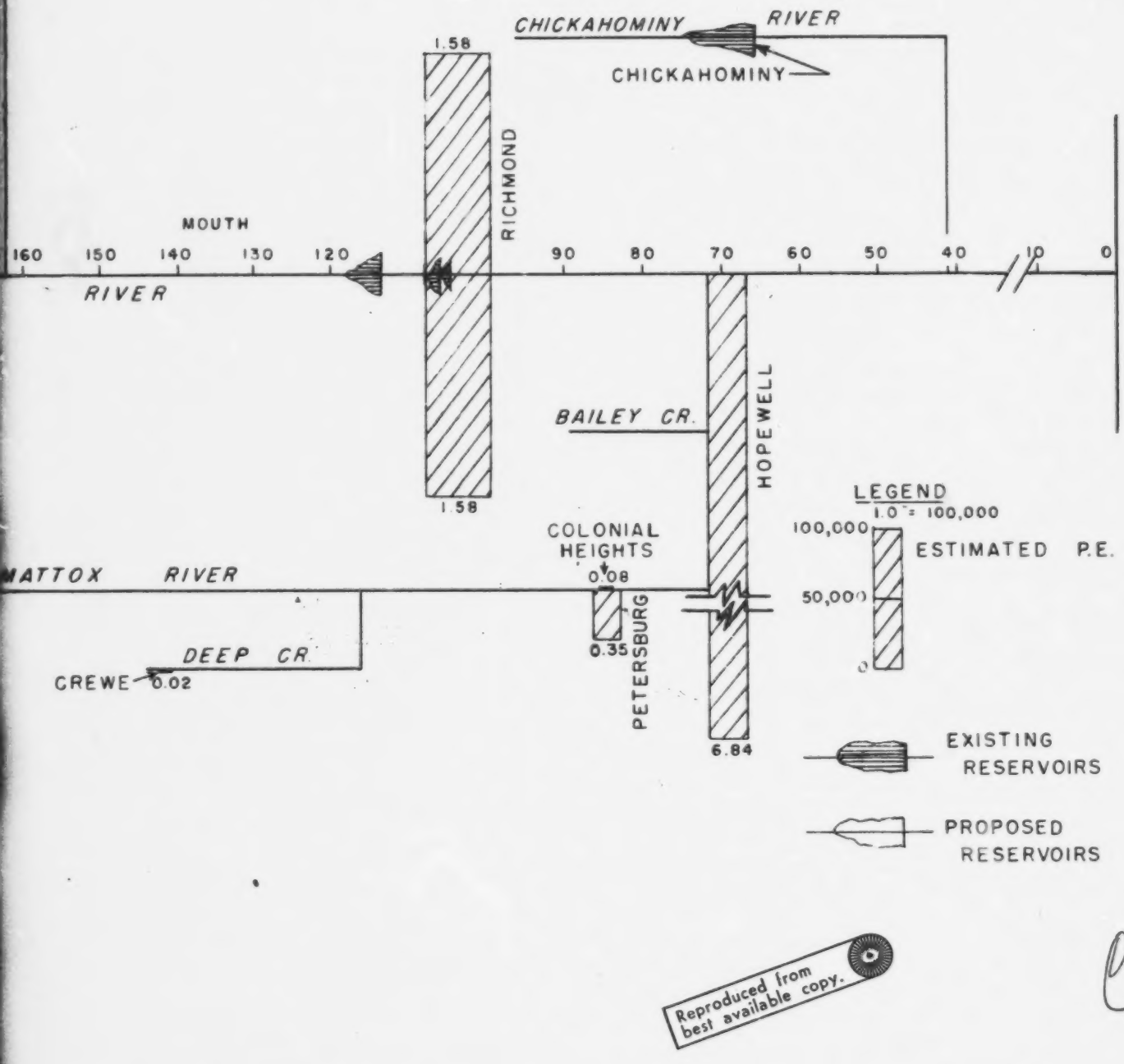

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FIGURE 1

made under the law. Considerable progress has been made, particularly considering the fact that an initial period of organization and inventorying of problems was necessary to make possible the development of a sound program for pollution abatement.

The Virginia Water Control Board adopted the following Regulation No. 1 at its meeting February 18-19, 1949:

"Every owner discharging raw untreated sewage into the waters of this State shall proceed immediately with the development of a program having as its purpose the substantial reduction in the pollution caused by the discharge of such sewage into the waters of the State, which program shall include the preparation of plans for such treatment plant and facilities as may be found necessary to accomplish such result. Every such owner shall file with the State Water Control Board on May 1, 1949, and at the end of every three-month period thereafter, a report showing the progress made by the owner in its pollution abatement program.

"This regulation shall become effective thirty days after the same has been filed with the Secretary of the Commonwealth as required by law."

The Virginia Water Control Board has adopted the following Regulation No. 2:

"Every owner who has been issued a certificate under Section 1514-B17 of the State Water Control Law to continue the discharge of industrial wastes into State waters shall proceed immediately with the development of a program having as its purpose the reduction of pollution resulting from such discharge.

"Reports showing the progress which has been made in developing and carrying out such a program shall be submitted to the State Water Control Board on 1 October 1949, and at the end of every three months period thereafter.

"This regulation shall become effective thirty days after it has been filed with the Secretary of the Commonwealth as required by law."

In the area which would be most affected by the Gathright-Falling Spring project, that is, the Jackson River and the James River above Lynchburg, notable progress has been made and is continuing, in

abatement of pollution. The largest industry in the area is the West Virginia Pulp and Paper Company. This industry employs some 2,500 people and produces about 600 tons of pulp and paper products per day. It operates on a 24-hour - 7-day week. It has decreased its waste discharge from 250,000 P.E. in 1947 to 125,000 P.E. at present. Since January 1, 1947, this industry has spent about $6,000,000 in plant remodeling and process changes and about $500,000 for air pollution control. The company is now installing activated sludge treatment for its wastes.

The City of Covington has final plans under preparation for primary treatment and chlorination. The estimated cost for interceptors, sewage treatment plant and land is $565,540. Bids for construction may be let this spring. Addition of secondary units in the future is planned.

The Industrial Rayon Corporation operates on a 24-hour - 7-day week and discharges daily to the Jackson River wastes containing 3,500 lbs of free acid (pH 2.6 - 2.9), though it has acid and caustic recovery in the plant. Reductions have been made in the waste load by recovery and process changes within the plant. During 1948 the biochemical oxygen demand of the wastes was reduced from 255 ppm to about 55 ppm.

The City of Clifton Forge, the second-largest community discharging to the Jackson River, submitted to a preliminary report in 1951 to the Water Control Board regarding primary treatment and chlorination for a design population of 10,000. The estimated cost (1951) for interceptors and sewage treatment plant construction amounted to $430,000.

The Keystone Tanning and Glue Company at Iron Gate has ceased operations, and it is not expected that operations will be resumed at a future date.

The National Container Corporation plant at Big Island produces about 150 tons pulp per day and discharges a daily waste load with a population equivalent of about 230,000. During 1949 the corporation reported a reduction of 76 per cent in the 1947 B.O.D. load through process changes and construction of lagoons. More recent figures (1952) show that the corporation has actually increased its B.O.D. load from a P.E. of 160,000 in 1947 to 220,000 - 250,000. Discharge from the lagoons is variable.

At Lynchburg the Mead Corporation produces about 130 tons of pulp and paper daily, using the semichemical process. The corporation has made some reduction in wastes through re-use of white water and recirculation of digester blowdown. Research has practically been completed on a pilot recovery plant investigation. An engineering design of a full-scale recovery plant to reduce wastes from digesters by 90 per cent is now in progress. Wastes discharged in October, 1952, had a daily population equivalent of 250,000.

The City of Lynchburg submitted a preliminary report in 1951 to the Water Control Board. Lynchburg is planning to construct a primary treatment plant with chlorination, for a design population of 60,000. The estimated cost (1951) for the sewage treatment plant is $1,035,000, and $1,715,000 for sanitary sewers, interceptors and outfall.

Richmond has submitted the Virginia Water Control Board a preliminary report, and plans to provide primary treatment for an initial population of 330,000 and some industrial wastes. The city has imposed a 100 per cent utility tax on water bills to provide funds for construction which is estimated to cost $16,000,000 for the sewage treatment

plant and interceptors. A 50 per cent increase in capacity will be added later for estimated 1985 population.

The Standard Paper Company, Richmond, actually has two plants with combined waste waters having a population equivalent of 13,000. Some reduction in wastes has been made through recovery and process changes. The company is being considered in the City's plans for sewage treatment.

The Manchester Board and Paper Company, Richmond, discharges wastes with a population equivalent of about 7,000. The company has made a slight reduction in wastes through process changes. The company may connect to the city sewer system when the municipal sewage treatment plant is built.

The Albemarle Paper Company, Richmond, discharges wastes with a population equivalent of 2,300. Some reduction in wastes has been obtained through plant changes such as save-alls.

The Virginia-Carolina Chemical Corporation, Richmond, is a tobacco by-products plant and manufactures agricultural insecticides and fertilizer material. It has reduced its waste load by process changes from a population equivalent of 13,800 to 12,000. These wastes contain nicotine, which is a toxic organic compound.

The E. I. du Pont Spruance Plant near Richmond manufactures cellophane and rayon. Through process changes and recovery, about a 55 per cent reduction in wastes, from a population equivalent of 110,000 to 50,000 has been made since 1940.

The Hummel Ross Division of the Continental Can Company, Hopewell, Va., discharges daily wastes with a population equivalent of 175,000. The plant has made some reduction in wastes through plant changes.

James Lees and Sons, Glasgow, Va., is a woollen mill which manufactures rugs. It has reduced its waste from a P.E. of 28,000 to 12,000 by settling and acid cracking, which effects a B.O.D. reduction of 60 per cent and a 97 per cent removal of grease.

Sewage treatment plants discharging to the James River were completed at Lynchburg State Colony, Beaumont Industrial School and the State Industrial Farm for Women (Goochland) in 1950, 1952 and 1953, respectively, at costs of $100,000, $27,000 and $30,000.

Sewage treatment plants discharging to tributaries of the James River were completed at Blue Ridge Sanitarium (Rivanna River) $60,000 in 1950; Petersburg Federal Reformatory (Appomattox River) $35,000 in 1950; Hampden-Sydney College (Little Buffalo Creek - Appomattox River) $40,000 in 1949; and Colonial Heights (Old Town Creek - Appomattox River) $200,000 in 1952.

A number of small communities in the James River basin have filed reports or plans with the Virginia Water Control Board regarding construction of sewage treatment plants. These include: Alleghany County, Selma, Iron Gate, Richmond Quartermaster Depot, Hopewell, Lexington, Buena Vista, Charlottesville, Petersburg and Crewe.

The previously cited examples indicate that considerable progress is being made in abatement of pollution in the James River Basin.

Effect of Proposed Gathright-Falling Spring Project

Flow regulation would be an extremely valuable part of a comprehensive pollution abatement program on the Jackson and upper James Rivers. Together with a general program of waste treatment and other

measures aimed at reducing the pollution load, flow regulation can increase the usefulness of the James River for public water supplies, for agricultural and industrial use, for recreation and for wildlife conservation. Flow regulation under the conditions surrounding this situation cannot be considered a substitute for measures aimed at reducing the waste load discharged to the streams, but it can be an extremely valuable supplement to treatment and recovery practices.

The proposed Gathright-Falling Spring project would increase the flow of the Jackson River at Covington below Dunlop Creek from its present minimum monthly low flow of 80 cfs to an average of 410 cfs during the midsummer months. This increase would be felt throughout the length of the Jackson River and the James River above tidal influence. The percentage increase would decrease as one proceeds downstream, but the increase would be noticeable as far downstream as Richmond.

In the Public Health Service report of May, 1945, the value of flow increases from the proposed Gathright-Falling Spring project was estimated at $200,000 annually, based on prewar price levels. In a review report dated April, 1949, this value was increased to $350,000. At present price levels and considering the present pollution load to the Jackson and upper James Rivers, the value of a proposed regulated flow increase of the Jackson River to 300 cfs minimum daily flow would be about $143,000. Residual monetary benefits from regulated flows are presented in table 2.

The monetary value of flow regulation was estimated as the cost of achieving similar improvements in water quality by other means. The estimates are conservative. Ordinarily, the cost benefit is computed as the difference in cost between primary and secondary sewage treatment,

between intermediate and secondary treatment or between secondary and tertiary treatment. On the Jackson River the cost benefit was computed as the difference in cost between secondary and tertiary sewage treatment; on the James River below Big Island and Lynchburg the cost benefit was computed as the difference in cost between primary and secondary treatment and below Richmond as the difference in cost between intermediate and secondary treatment.

Flow regulation will have some beneficial effects which are not obtained by reducing the pollution load. The usefulness of the stream for recreation and for aquatic life will be greater with increased minimum flows, and any additional water provided will be available for public or industrial water supply purposes. These benefits have not been included because of the impossibility of placing a monetary value on them. The towns and industries have enough water for their present and prospective needs.

On the other hand, flow regulation will not correct some of the present difficulties as effectively as will measures aimed at reducing the pollution load. For instance, the taste and odor problems in water supplies due to industrial waste discharges are not solved as well by increasing low flows as they are by methods which prevent the entrance of the offending substances into the stream. This factor has been considered in making the estimates of benefits. The above estimates of benefits and the estimates appearing in table 2 are 25 per cent less for the industrial portion of the pollution load than the estimated cost of providing the high degree of treatment required without flow regulation to maintain the same dissolved oxygen level (5 ppm) in the stream.

This method of estimating the monetary value of benefits is the most feasible method available because of the impossibility of evaluating the many intangible benefits of pollution abatement directly. It is not a precise method. It is simply a rational and practical method.

Monetary Benefits

From a study of major sources of pollution to the James River, it appears that possible benefits to pollution abatement may be found on the Jackson River below Covington, the James River below Big Island and below Richmond. Because of the pattern of hydroelectric operations at Reusen's Dam above Lynchburg, it does not appear that any benefits can be found on the James River in the section just below Lynchburg. Benefit estimates and flows required to secure these benefits are shown in table 2.

In a typical case of pollution from a city or industry entering a stream, the objectionable conditions resulting can be corrected in large measure by treatment, the degree or efficiency of treatment required being dependent on the size of the city or industry in relation to the minimum flow in the stream. For example, a moderate sized or large city on a small stream requires an elaborate treatment plant accomplishing a high degree of purification. On a larger stream, the same city or industry might well find that a partial treatment would suffice. It follows that if the flow in an outlet watercourse is increased, it may be possible for a partial treatment to abate pollution at a lesser cost. Under such circumstances the savings in cost can quite justifiably be credited to the increase in flow as a benefit. This approach assumes that there is ample

justification for correcting the pollution because of the benefits of a clean stream, or that abatement of pollution is required by common law, state legislation or court decision.

When municipalities or industries are tremendously large in relation to the minimum flow in a stream, there arises a question as to the possibility of maintaining satisfactory stream conditions regardless of the degree of treatment used. In other cases, when a large industry is of such a type that reasonable and economical methods of treatment are not known, there are practical difficulties which prevent the prompt correction of serious stream pollution conditions. In these two situations, increased flows are highly desirable and valuable, in that such flows will accomplish a pollution abatement that can be accomplished by no other means.

In the event municipalities or industries construct secondary treatment plants after construction and operation of the Gathright-Falling Spring Reservoir project, the increased low flow will still justify the estimated monetary benefits. Secondary treatment will result in a higher standard of quality being maintained in the Jackson and James Rivers. The benefit would represent the difference in cost between secondary and tertiary sewage treatment.

These preceding statements should clarify the thinking used in calculating monetary benefits from low flow augmentation and should satisfy the criteria to be complied with in the Bureau of the Budget Circular No. A-47 dated 31 December 1952 which states as follows:
"c. Savings in the cost of water treatment or gains in the value of streams for industrial, municipal, and domestic water supply, and other uses, through the abatement of water pollution; and reduction in the cost

of pollution abatement by stream flow augmentation. Such benefits should be calculated as the residual benefit possible after allowing for all direct measures to control pollution at the source that would normally be required or considered necessary by the public health authorities concerned".

Objectives

The objective of pollution control activities has been assumed to be the maintenance of 5 parts per million daily minimum dissolved oxygen over most of the months of the year. Because of excessively high water temperatures during the midsummer months, there are limitations on possible accomplishments, both by sewage treatment and by flow regulation and the midsummer objective has been tentatively set somewhat lower. Occasionally, for example, a further drop in the daily minimum dissolved oxygen is taken as permissible provided the drop is of short duration, is confined to a short section of the river, and is not below 4.0 parts per million.

Hydrology

For the months of June through September the minimum average unregulated flow in a calendar month that may be expected at 10 year intervals below Covington* is 95 cfs, below Big Island# 510 cfs and below Richmond, 1220 cfs.

Benefit Estimates

In determining estimates below Covington, Big Island and Richmond, it was not possible to prepare estimates for the cost of reducing pollution by treatment methods to produce the same improvement as that produced by

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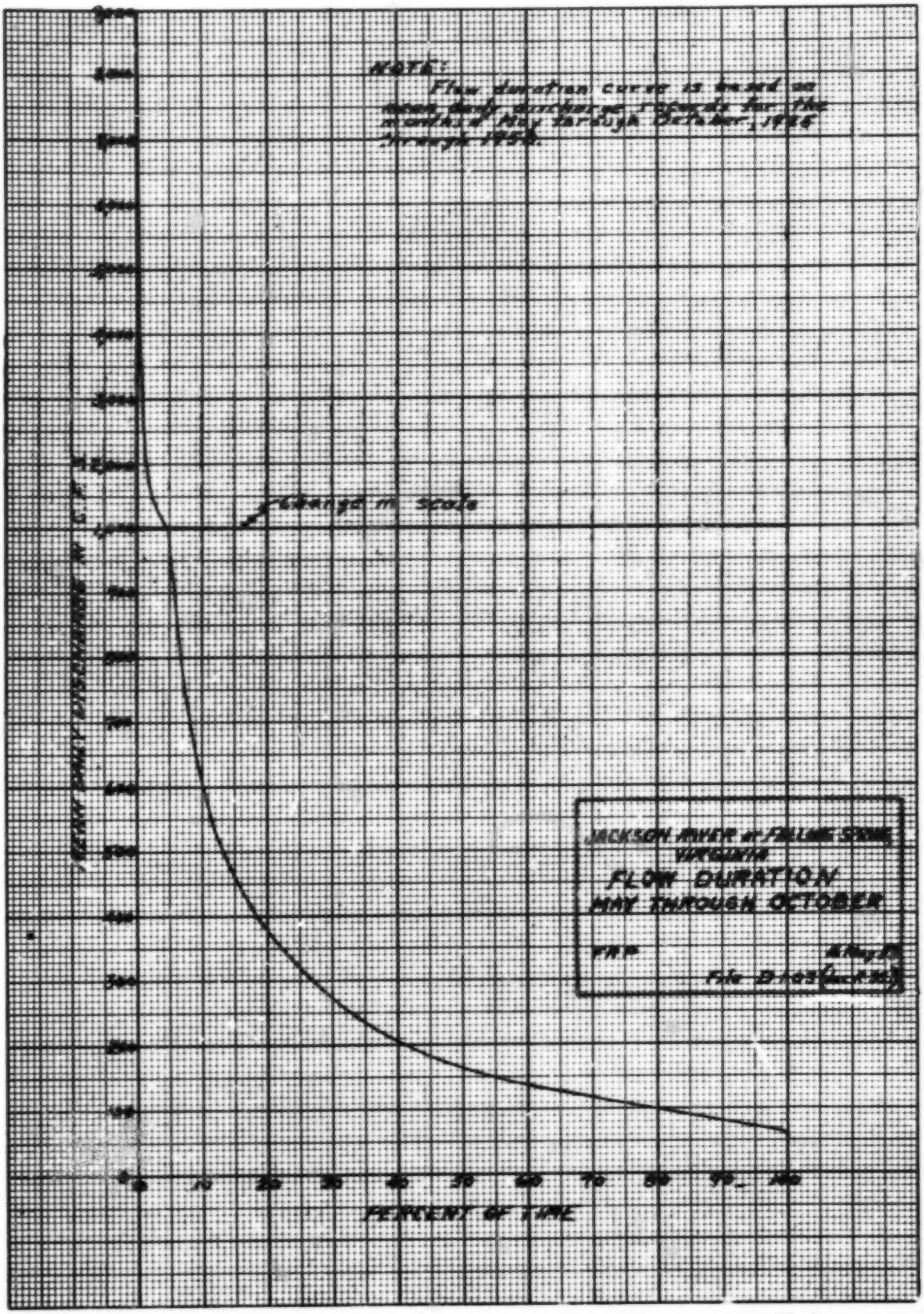
* Below mouth of Dunlap Creek. Computed from gages on Jackson River at Falling Spring and Dunlap Creek near Covington.
# At Holcombs Rock


NOTE:
Flow duration curve is based on
records of discharge measured for the
months of May through October 1946
through 1955.
change in scale
JACKSON RIVER at FALLING SPRING
VIRGINIA
FLOW DURATION
MAY THROUGH OCTOBER
FMP
File D-103
PERCENT OF TIME

7 Apr 53

SUMMER LOW FLOW FREQUENCY, JAMES RIVER BASIN (A)*

Stream	Gage	James River mile	Drainage area, sq.mi.	Period of record, years	Minimum average flows, cfs: In 7 consecutive days — Experienced in period of record	In 7 consecutive days — Expected at 10 year intervals	In calender month — Experienced in period of record	In calender month — Expected at 10 year intervals
Jackson	Falling Springs	375.5	409	27	60	68	62	76
Jackson	Covington (B)	363.6	613	22	84	86	83	95
James	Buchanan	301.2	2084	54	270	310	289	370
James	Holcombs Rock	263.2	3250	25	368	430	421	510
James	Cartersville	152.4	6242	53	446	820	561	1140
James	Richmond	111.7	6757	14	743	800	1004	1220

(A) During June through September.
(B) Below mouth of Dunlap Creek. Computed from gages on Jackson River at Falling Spring and Dunlap Creek near Covington.

* Chart is from Corps of Engineers, Norfolk District

13.B

increased flow. The reason this was not possible is that specific methods to be used are not known for the industrial wastes involved with the exception of the West Virginia Pulp and Paper Co.* For industrial wastes, estimates have been based chiefly on removing an equivalent amount of pollution by supplemental sewage treatment above primary, such as by secondary units in a complete sewage treatment plant or by intermediate units in an intermediate treatment plant. A figure of $2.33 was used as the cost of removing one population equivalent by secondary units in a complete sewage treatment plant. This figure was arbitrarily halved and the resultant figure used as the cost of intermediate treatment units. The derivation of the $2.33 annual cost per sewered population equivalent removed by secondary treatment units, using Ohio River Pollution Survey cost data** adjusted to March, 1953 ENR index (507) and operational cost data from averages of plants of comparable size for the year 1951***, is as follows:

	Design Population 68,000			
Treatment	Estimated Cost	Interest and Amortization(1)	Operation & Maintenance	Total Annual Charges "X"
Complete	1,620,000	104,000	117,600	221,600
Primary	996,000	63,900	78,400	142,300
Sec. treatment units	624,000	40,100	39,200	79,300

Treatment	Purification Efficiency Percent	Sewered Population Equivalent Removed "Y"	Total Annual Charges per Sewered Population Equivalent Removed $\frac{"X"}{"Y"}$
Complete	85	57,800	-
Primary	35	23,800	-
Difference (secondary unit)	50	34,000	2.33

(1) Cost x 0.06415 based on 2 1/2% interest and 20 year life.

* The West Virginia Pulp and Paper Company plans to install an activated sludge type treatment plant for its wastes.

** Engineering News-Record

*** Operational and maintenance costs have increased some but not materially since the end of 1951.

For industrial plants the same figure, $2.33, was used but was reduced by 25 per cent to $1.75 since the taste and odor constituents of industrial wastes are seldom diluted to an extent sufficient for disappearance and therefore it was deemed reasonable to assess a penalty of 25 per cent to the monetary benefits from dilution. No rational basis for determining the magnitude of the penalty is possible; it is merely an arbitrary estimate. Because of the creation of water supply tastes and odors by industrial wastes, the use of dilution water is less of a complete solution to the problem than it is in the case of residual pollution following treatment of municipal sewage. The disposal by dilution of the effluent from a municipal treatment plant treating domestic wastes is a satisfactory solution to the problem but the same is not true in the case of industrial wastes.

Dilution Ratios

From a study of the laboratory results obtained in 1944 and by applying oxygen balance analyses with a conservative safety factor, it was determined that the following dilution ratios would be required to maintain 5 ppm dissolved oxygen in the stream during the worst conditions of the summer months: below Covington 2.3 cfs per 1,000 population equivalents; below Big Island 7.5 cfs per 1,000 P.E.; below Lynchburg 7.2 cfs per 1,000 P.E.; and below Richmond 10 cfs per 1,000 P.E.

Below Covington

Applying the dilution ratio, it is concluded that the Jackson River below Dunlap Creek is capable of assimilating pollution with a sewered population equivalent of 41,000 during a dry period occurring once in 10 years. Following regulation by Gathright Reservoir, the

stream will have a capacity for assimilating pollution from a sewered population equivalent of 174,000 (400 cfs flow in Jackson River). In both cases it is assumed that 5 ppm dissolved oxygen in the river is maintained. At present the pollution in the Covington area has a population equivalent of 146,000. Therefore, the pollution corrected by the increased dilution afforded by proposed increased flow from Gathright amounts to a population equivalent of 105,000, although it is capable of assimilating more pollution than that. However, since the municipalities and the West Virginia Pulp and Paper Company who discharge the pollution, plan to eventually install secondary treatment, the pollution to the stream will be reduced by 85% which leaves 22,000 P.E. Residual monetary benefits are calculated on the basis of tertiary treatment using the unit value for secondary treatment and applying the penalty of 25 per cent to the industrial portion. Using the unit value of $2.33 for municipal and $1.75 for industrial, a benefit of $40,400 is obtained, as follows: industrial P.E. 125,000; municipal P.E. 21,000; $\frac{21,000}{146,000} = 0.14$ $\frac{125,000}{146,000} = 0.86$

Then 22,000 x 0.14 = 3,100 municipal portion

22,000 x 0.86 = 18,900 industrial portion.

and $2.33 x 3,100 + $1.75 x 18,900 = 7,200 + 33,200 = $40,400.

Below Big Island

The National Container Corporation is the source of pollution at Big Island and discharges pollution with a population equivalent of 233,500. Applying dilution ratios, it is concluded that the James River below Big Island is capable of assimilating pollution with a sewered

population equivalent of 68,000. Following low-water augmentation (300 cfs) by Gathright Reservoir, the stream will have a capacity for assimilation of a sewered population equivalent of 108,000. The pollution corrected by 300 cfs flow increase supplied by Gathright Reservoir amounts to a population equivalent of 40,000. It is expected that the National Container Corporation will eventually introduce plant and process changes which will decrease the pollution discharge by 50 per cent, reducing the discharge to a population equivalent of 116,750. On this basis the full 300 cfs increase in flow from Gathright will still be needed as correction for pollution and will reduce pollution by a population equivalent of 40,000. Using the basic value of $2.33 per P.E. removed by dilution and applying a 25 per cent penalty for an industrial waste which converts the unit value to $1.75, the monetary benefit realized below Big Island is 40,000 x $1.75 = $70,000.

Below Lynchburg

No monetary benefits for low stream flow augmentation can be assigned to the stream section below Lynchburg because of the pattern of hydroelectric operations at Reusen's Dam. Examination of hydrographs of hourly plant discharges from Reusen's Hydro Plant of the Appalachian Power Company indicate that even with flows in excess of those which would be present during dry summer weather with flow augmentation of 300 additional cfs from Gathright peaking operations persisted for 5 to 8 hours or more, continuously. Such operations nullify any monetary benefit for pollution abatement from increased flow. If operations at Reusen's Hydro Plant were altered so that the 300 cfs of flow augmentation were released continuously, then the monetary benefits from this

amount of water based on the difference in cost between primary and secondary sewage treatment would amount to $79,800.

Below Richmond

The city of Richmond plans to provide primary treatment for an initial population of 330,000 and some industrial wastes. The 1950 census lists a population of 230,000 for Richmond. Industrial plants in the Richmond area discharge pollution with an approximate population equivalent of 85,200. Applying the dilution ratio of 10 cfs per 1,000 P.E., it is concluded that the James River below Richmond is capable of assimilating pollution with a sewered population equivalent of 122,000. Augmentation of low flow by 300 cfs from Gathright will assimilate additional pollution amounting to 30,000 P.E. and thus bring the total capacity of the river for assimilation of pollution to 152,000 P.E. If it is assumed that some of the industries will connect to the proposed Richmond Primary Treatment Plant and the others provide the equivalent of primary treatment, then the present pollution load to the river will be decreased by 35 per cent or 115,000 P.E. leaving 200,000 P.E. Even with low flow augmentation additional treatment will be necessary at Richmond. Assuming Richmond installs intermediate treatment, then the unit value per P.E. removed by dilution will be $1.16 for the municipal portion of pollution and $0.88 for the industrial portion. The total monetary benefit from dilution below Richmond is calculated as follows:

Municipal pollution = $\frac{230,000}{315,000}$ x 100 = 73% of total

Industrial Pollution = 100 - 73 = 27% of total

Dilution from 300 cfs will remove 30,000 P.E.

30,000 x 0.73 x $1.16 = $25,400

$$30,000 \times 0.27 \times \$0.88 = \frac{\$7,200}{\$32,600}$$

The total monetary benefit below Richmond from 300 cfs of low flow augmentation by Gathright Reservoir amounts to $32,600.

Total Monetary Benefit from Pollution Abatement from Low Flow Augmentation by Gathright Reservoir

The total monetary benefit that can be assigned to pollution abatement from low flow augmentation (300 cfs) by Gathright Reservoir is $143,000. This figure was calculated with consideration of satisfying the criteria to be complied with in the Bureau of the Budget Circular No. A-47 dated 31 December 1952 which were cited earlier in this report. If the operations at Reusen's Hydro Plant permitted the continuous release of the water flow augmentation by Gathright Reservoir, then the total monetary benefits for pollution abatement that can be assigned to the Gathright project would be increased by $79,800.

Flow to be Released from Gathright Project While Impounding

The amount of flow to be released from the Gathright project while impounding will be an arbitrary figure based on compromise. On the one hand it is desirable to have adequate flow for pollution abatement, and on the other hand it is desirable to release as little flow as possible so that the reservoir may be filled in a shorter period.

Assuming that Covington and Clifton Forge have constructed primary sewage treatment plants by the time the Gathright project is completed and the pollution load to the Jackson River by the West Virginia Pulp and Paper Company is decreased 85 per cent by activated sludge

Table 2 - James River Reinvestigation - Estimated Minimum Monthly Discharges Required to Secure Indicated Tangible Monetary Benefits to Pollution Abatement at Points in the James River Basin

Month	Estimated Minimum Monthly Discharge in Cubic Feet per Second to Secure Monetary Benefits			
	Covington below Dunlap Creek (Assuming Pollution receives secondary treatment before discharge)	Below Big Island (Assuming present pollution load is reduced by 50%)	Below Lynchburg (Assuming present pollution is reduced by 50%)	Below Richmond (Assuming pollution receives intermediate treatment before discharge)
January	70	330	440	560
February	70	330	440	560
March	70	330	440	630
April	85	430	640	820
May	120	600	800	1070
June	155	770	1090	1440
July	170	810	1180	1520
August	170	810	1180	1520
September	150	680	910	1320
October	85	460	610	880
November	70	330	440	630
December	70	330	440	560
Summer Average, May through October	140	690	960	1290
Yearly Average	105	520	730	960
Annual Benefits	$40,400	$70,000	No benefits*	$32,600

* Benefits that would ordinarily be assigned to the stream stretch before Lynchburg are nullified by the pattern of hydroelectric operations at Reusen's Dam. If the hydroelectric operations at Reusen's Dam permitted the continuous release of the flow augmentation by the Gathright Project, the annual monetary benefits in the amount of $79,800 could be assigned to the Gathright Project for pollution abatement below Lynchburg.

treatment, then 120 cfs flow in the Jackson River is adequate for dilution purposes during the warm summer months to maintain 5 ppm dissolved oxygen in this stream. Figure 2 shows that such a natural flow(120 cfs) or less can be expected about 70 per cent of the days during the dry part of the year, May through October, based on water years 1945-1949.

It is recommended that the naturally-occurring flow of the Jackson River up to 120 cfs be released while impounding water for the Gathright-Falling Spring project during the months of May through October and up to 70 cfs be released during the months of November through April.

Discussion

The benefits which would be derived from a comprehensive pollution abatement program on the upper James River, including the proposed Gathright-Falling Spring project, would be widespread. All who use the waters of the Jackson and upper James Rivers, for water supply, for recreation, for industrial use, or for agricultural use, would benefit.

The most economical pollution abatement program for this area would include interception and treatment of sewage; reduction of the industrial waste load by recovery practices, process changes and treatment methods; and dilution of treated wastes by flow regulation from the proposed Gathright-Falling Spring project.

Because flow regulation is an important part of a comprehensive pollution program and would be less beneficial without the other parts of the program, there should be assurance that the necessary and possible measures for reducing the waste load by treatment and recovery

practices are being or will be taken. Considerable progress has been made in reducing the pollution load along the Jackson and upper James Rivers, and the program for pollution abatement now in progress under the authority of the Virginia Water Control Board gives assurance that the necessary pollution abatement measures will be taken. Thus the provision of low-flow regulation by the proposed Gathright-Falling Spring projects will provide the benefits as previously estimated. Although it is not possible to give an exact figure, it is estimated that the provision of the necessary intercepting sewers, treatment plants and industrial waste corrective measures will cost local interests about $21,000,000. This is in addition to the $6,310,000 in expenditures which have already been made.